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3.29 DOPPLER TRACK

In addition to the usual measurement of target angle and range, some radars use coherent processing which permits the extraction of relatively small frequency shifts in reflected radar energy caused by target motion. This frequency shift is known as the Doppler shift, f_d and is related to the relative motion between the target and radar by the equation:

$$f_d = \frac{2\vec{v}_t \cdot \vec{r}}{|\vec{r}|}$$

where v_t is the target velocity, r is the position vector from the target to the radar, and   is the radar wavelength.

A coherent radar must track the change in target Doppler as a function of time and will use tracking filters similar to angle and range tracking filters. The input to the tracking filter is the Doppler error which is determined by the frequency discriminator which compares the measured Doppler to the frequency of a variable controlled oscillator (VCO). The Doppler discriminator typically consists of a bank of Doppler filters centered around the VCO frequency that determines the Doppler frequency to a precision related to the filter bandwidth. Currently, ESAMS uses a perfect Doppler discriminator that passes the true Doppler frequency of the target to the Doppler track filter.

3.29.1 Objectives and Procedures

The objective of this analysis was to vary the servo gain in a representative Doppler track servo and examine the effect on the step response and overall radar tracking and missile flyout performance. The Doppler track servo type is specified by the RDRD variable IDSTYP, and for this analysis, we selected a semi-active homing missile with the servo type given by IDSTYP(3)=6.

As for the angle and range track analyses, the step response was obtained by identifying the appropriate subroutines that model the servo and its initialization and developing a driver to input the step input. For IDSTYP(3)=6, the appropriate servo subroutine is SDOPC. The sensitivity analysis consisted of varying one of the filter constants, which corresponds to FLCOEF(48) in the RDRD file, from the default value of 2.5 to 5.0 and 10.0. Filter rise and settling times were examined, as well as their effect on seeker tracking errors and missile flyout performance. The target engagement consisted of a 1.0 m^2 target flying toward the SAM site starting at an up-range of 2500 m and a cross-range of 4000 m. The seeker Doppler tracking errors are obtained from the seeker output on logical unit 51, and the missile trajectory is available in the standard output file.

3.29.2 Results

The filter step response is plotted in Figure 3.29-1 for gain values of 2.5 (the default), 5.0, and 10.0. Increasing the gain shortens the rise time and settling time for the filter. There is also more filter "ringing" or oscillation with higher gains.
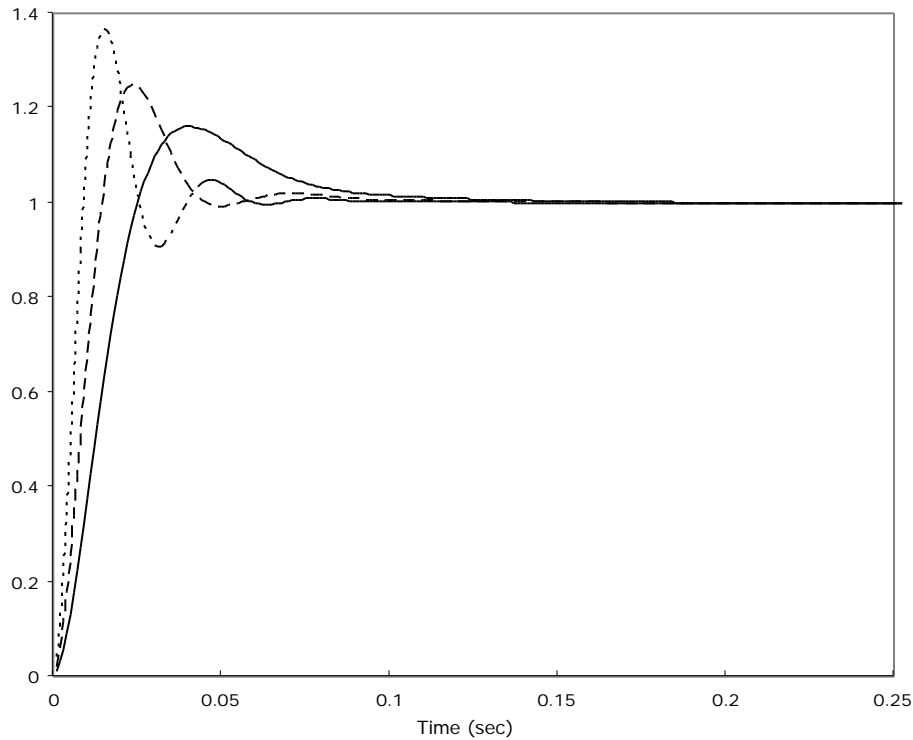
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FIGURE 3.29-1. Step Responses for Doppler Track Servo as a Function of Servo Gain.

Seeker tracking errors for different Doppler servo gains are plotted in Figure 3.29-2. For each of the filter gains, there is an approximately linear buildup in tracking errors until about 8.5 seconds. The reason for this is that the ESAMS simulation for this particular missile does not allow the seeker variable controlled oscillator (VCO) to be updated until after the boost phase. After this time, the VCO locks onto the measured target Doppler and the missile successfully guides to intercept with all three filter gains.
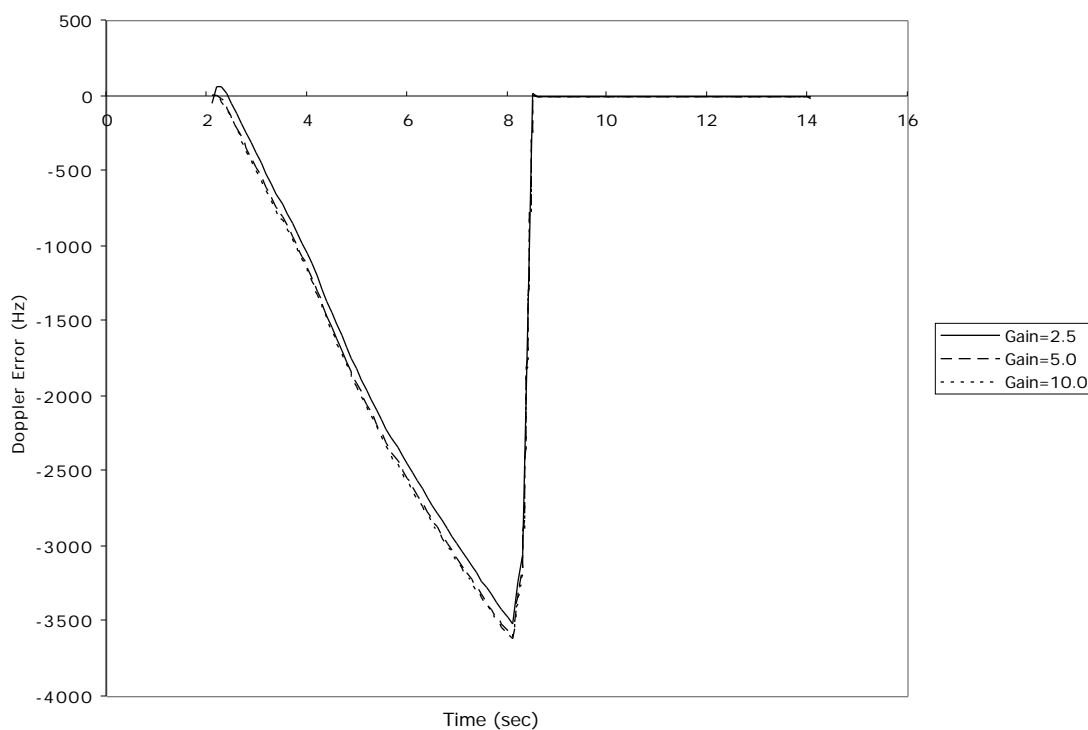
FIGURE 3.29-2. Missile Doppler Tracking Errors as a Function of Servo Gain.

There are some differences in tracking error for different gains as illustrated in the blow-up in Figure 3.29-3; however, the errors are sufficiently small that there is no significant effect on the missile flyout trajectory or miss distance.
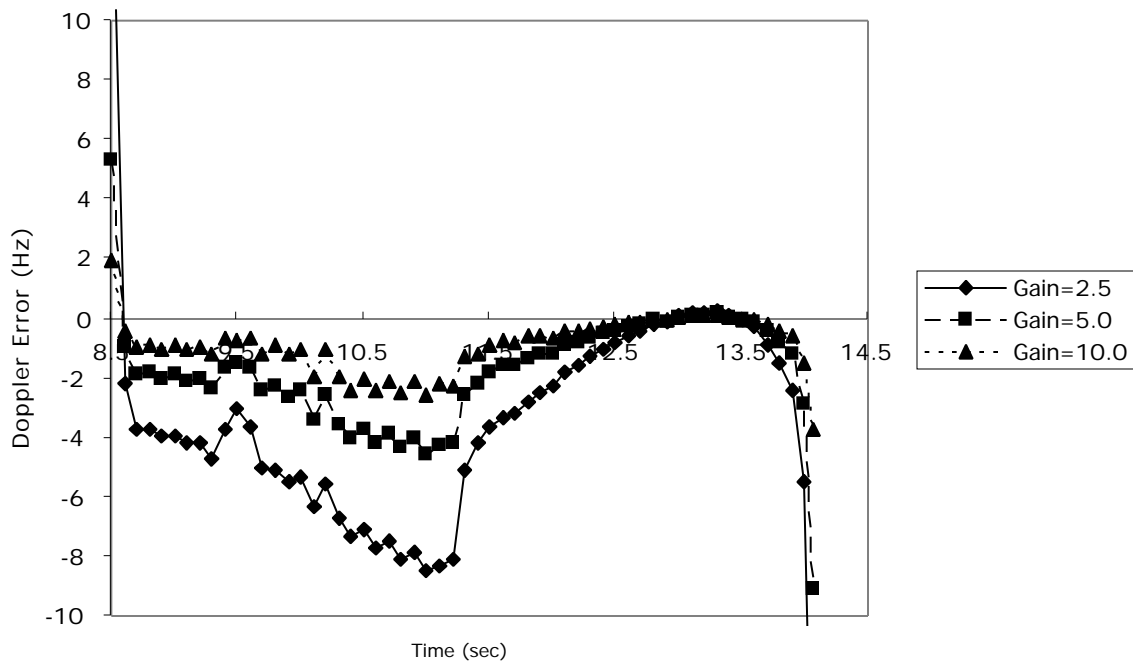
FIGURE 3.29-3. Missile Doppler Tracking Errors as a Function of
Servo Gain (Expanded Scale).

In Figure 3.29-3, Doppler tracking errors increase to a maximum at about 11 seconds. This is approximately the time that the missile pitches over and is most stressing portion of the flyout prior to the endgame for the Doppler servo. The small differences in Doppler tracking errors corresponding to the different filter gains have no significant affect on the missile flyout trajectory or endgame modeling.

3.29.3 Conclusions

Doppler tracking errors in ESAMS are unrealistically small and relatively insensitive to the Doppler filter characteristics. This is largely the result of using a perfect velocity discriminator. By changing the filter gain, significantly different step responses can be obtained. Higher gain results in larger Doppler tracking errors; however, missile flyout trajectories and miss distances were unaffected for the engagement conditions examined.